WHAT IS CLAIMED IS:

1. Apparatus for efficiently detecting neutrons, the apparatus comprising:

a particle-detecting first substrate having first and second surfaces spaced apart by a region of the substrate and a plurality of cavities extending into the substrate from the first and second surfaces; and

neutron- responsive material disposed in the plurality of cavities, the material being responsive to neutrons absorbed thereby for releasing ionizing radiation reaction products, wherein the neutron-responsive material disposed in the cavities at the first and second surfaces increases neutron-detection efficiency by increasing the likelihood that the reaction products will be directed into the substrate for increased neutron-detection efficiency.

2. The apparatus as claimed in claim 1, further comprising a first contact layer disposed on the first surface; and

a second contact layer disposed on the second surface.

3. The apparatus as claimed in claim 2, wherein the first and second contact layers are also disposed in the plurality of cavities.

4. The apparatus as claimed in claim 1, wherein the plurality of cavities include etched via holes.

5. The apparatus as claimed in claim 1, wherein the plurality of cavities include etched trenches or slots.

6. The apparatus as claimed in claim 1, wherein the neutron-responsive material is also disposed as at least one cap layer on the first and second surfaces.

7. The apparatus as claimed in claim 1, wherein the neutron-responsive material disposed in the cavities at the first surface is of a first type

different from a second type of neutron-responsive material disposed in the cavities at the second surface.

8. The apparatus as claimed in claim 1, wherein the neutrons are thermal neutrons.

9. The apparatus as claimed in claim 1, wherein the cavities extending into the substrate from one of the surfaces are surrounded by cavities extending into the substrate from the other of the surfaces.

10. The apparatus as claimed in claim 1, wherein the first substrate is composed primarily of a semiconductor material.

11. The apparatus as claimed in claim 10, wherein the semiconductor material is silicon, silicon carbide, gallium arsenide, gallium nitride, indium phosphide, cadmium telluride, cadmium-zinc-telluride, gallium phosphide, mercuric iodide, or lead iodide.

12. The apparatus as claimed in claim 1 further comprising a particle-detecting second substrate having neutron-responsive material disposed in cavities of the second substrate and stacked on the first substrate.

13. The apparatus as claimed in claim 12, wherein the neutron-responsive material is also disposed as layers between the substrates.

14. The apparatus as claimed in claim 1, wherein different types of neutron-responsive material are disposed in each of the plurality of cavities.

15. The apparatus as claimed in claim 14, wherein the neutron-responsive material is also disposed as a plurality of layers of different types of neutron-responsive material on both the first and second surfaces.

16. Apparatus for efficiently detecting neutrons, the apparatus comprising:

a particle-detecting first substrate having first and second surfaces spaced apart by a region of the substrate;

a first contact layer disposed on the first surface of the substrate;

a second contract layer disposed on the second surface of the substrate; and

a first stack of neutron-responsive layers, including a first layer of neutron-responsive material of a first type disposed on the first contact layer and a second layer of neutron-responsive material of a second type different from the first type disposed on the first layer, both of the materials being responsive to neutrons absorbed thereby for releasing ionizing radiation reactive products.

17. The apparatus as claimed in claim 16, wherein the first layer has a higher neutron interaction cross section than the second layer.

18. The apparatus as claimed in claim 16, wherein the first and second types of material include elemental or compound forms of lithium, lithium fluoride, boron, gadolinium, plastic, cadmium, U^{235}, Pu and Th.

19. The apparatus as claimed in claim 16, wherein the first substrate is composed primarily of a semiconductor material.

20. The apparatus as claimed in claim 19, wherein the semiconductor material is silicon, silicon carbide, gallium arsenide, indium phosphide, cadmium telluride, cadmium-zinc-telluride, gallium phosphide, mercuric iodide, or lead iodide.

21. The apparatus as claimed in claim 16 further comprising a particle-detecting second substrate having at least one neutron-responsive layer disposed on a contact layer of the second substrate and stacked on the first substrate.

22. The apparatus as claimed in claim 21, wherein the layers of neutron-responsive material are disposed between the substrates.

23. The apparatus as claimed in claim 16 further comprising a stack of neutron-responsive layers disposed on the second contact layer.

24. Apparatus for efficiently detecting neutrons, the apparatus comprising:

a particle-detecting first substrate having spaced first and second surfaces and a plurality of different-sized cavities extending into the substrate from the first and second surfaces; and

neutron-responsive material disposed in the plurality of different-sized cavities, the material being responsive to neutrons absorbed thereby for releasing ionizing radiation reaction products, wherein the neutron-responsive material disposed in the different-sized cavities at the first and second surfaces increases neutron-detection efficiency by increasing the likelihood that the reaction products will be directed into the substrate for increased neutron-detection efficiency.

25. The apparatus as claimed in claim 24, further comprising a first contact layer disposed on the first and second surfaces; and

a second contact layer disposed on a third surface of the substrate spaced apart from the first and second surfaces by a region of the substrate.

26. The apparatus as claimed in claim 25, wherein the first contact layer is also disposed in the plurality of cavities.

27. The apparatus as claimed in claim 24, wherein the plurality of cavities include etched large and small via holes.

28. The apparatus as claimed in claim 24, wherein the neutron-responsive material is also disposed as a layer on the first and second surfaces.

29. The apparatus as claimed in claim 24, wherein the neutron-responsive material disposed in the cavities at the first surface is of a first type different from a second type of neutron-responsive material disposed in the cavities at the second surface.

30. The apparatus as claimed in claim 24, wherein the neutrons are thermal neutrons.

31. The apparatus as claimed in claim 24, wherein the cavities are generally circular in cross section.

32. The apparatus as claimed in claim 24, wherein the neutron-responsive material includes elemental or compound forms of lithium, lithium fluoride, boron, gadolinium, cadmium, any form of plastic, U^{235}, Pu or Th.

33. The apparatus as claimed in claim 24, wherein the first substrate is composed primarily of a semiconductor material.

34. The apparatus as claimed in claim 33, wherein the semiconductor material is silicon, silicon carbide, gallium arsenide, gallium nitride, indium phosphide, cadmium telluride, cadmium-zinc-telluride, gallium phosphide, mercuric iodide, or lead iodide.

35. The apparatus as claimed in claim 24, wherein relatively small cavities extending into the first substrate from one of the surfaces are disposed within relatively large cavities extending into the first substrate from the other surface.

36. The apparatus as claimed in claim 24 further comprising a particle-detecting second substrate having neutron-responsive material disposed in a plurality of different-sized cavities in the second substrate and stacked on the first substrate.

37. The apparatus as claimed in claim 36, wherein the neutron-responsive material is disposed as layers between the substrates.

38. The apparatus as claimed in claim 37, wherein at least two of the layers are of different neutron-responsive material.

39. Apparatus for efficiently detecting neutrons, the apparatus comprising:

a particle-detecting first substrate having first and second surfaces spaced apart by a first region of the first substrate and a first set of cavities extending into the first substrate from the first surface;

a particle-detecting second substrate stacked on the first substrate and having first and second surfaces spaced apart by a second region of the second substrate and a second set of cavities extending into the second substrate from the first surface of the second substrate; and

neutron-responsive material disposed in the first and second sets of cavities and on the first surfaces of the substrates, the material being responsive to neutrons absorbed thereby for releasing ionizing radiation reaction products, wherein the neutron-responsive material disposed in the first and second sets of cavities increases neutron-detection efficiency by increasing the likelihood that the reaction products will be directed into the first and second substrates, respectively, for increased neutron-detection efficiency.

40. The apparatus as claimed in claim 39, wherein the first and second sets of cavities are not aligned to further optimize neutron absorption.

41. The apparatus as claimed in claim 39 further comprising a first contact layer disposed on the second surface of the first substrate and a second contact layer disposed on the second surface of the second substrate.

42. A method of making a high-efficiency neutron detector, the method comprising:

providing a particle-detecting substrate having a first surface and a plurality of cavities extending into the substrate from the first surface;

filling the plurality of cavities with a neutron-responsive material; and

forming a thick film of the neutron-responsive material over the first surface including the plurality of cavities wherein the cavities relieve stress in the thick film to prevent delamination of the thick film from the first surface, the material being responsive to neutrons absorbed thereby for releasing ionizing radiation reaction products, wherein the neutron-responsive material disposed in the cavities at the first surface increases neutron-detection efficiency by increasing the likelihood that the reaction products will be directed into the substrate for increased neutron-detection efficiency.

43. The method as claimed in claim 42, wherein the thick film exceeds one micron in thickness.

44. A method of making a high-efficiency neutron detector, the method including providing a particle-detecting first substrate having a first surface and a plurality of cavities extending into the substrate from the first surface, and filling the plurality of cavities with a neutron- responsive material, the material being responsive to neutrons absorbed thereby for releasing ionizing radiation reaction products, wherein the neutron-responsive material disposed in the cavities at the first surface increases neutron-detection efficiency by increasing the likelihood that the reaction products will be directed into the substrate for increased neutron-detection efficiency, the improvement comprising:

the step of filling includes the step of spreading the material on the first surface and vibrating the material into the plurality of cavities.

45. The method as claimed in claim 44, wherein the material is submicron powder.